

DOCUMENT-IDENTIFIER: US 5797845 A
TITLE: Ultrasound apparatus for three dimensional
image reconstruction

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DEPR:

FIG. 12 describes the schematic of the generation of the acoustic wave packages and schematic of the signal processing of the echo signals. As it is seen from the figure, transmit and receive array systems are separated. The pulse driver 47 has timing circuitry and the necessary set of generators. They perform the functions of the transmit system 22 in the phased mode with dynamic focusing and scanning of the beam and are connected with individual elements 28 of the transmit array 22 by cables 48. Individual elements 28 of the receive array 23 register the echo signals and are connected by cables 45 with reception parts 49 and 50 of the apparatus which provides amplification of the echo signals, conversion of them in the digital code and recording of amplitude information from every receive array individual element in the memory for every focal distance. Adjustment of the dynamic receive apertures is produced by shifting the individual element information by the number of digits corresponding to the delay for every individual element. After this, individual element information is summed and presented as part of the acoustic line for every selected aperture. Thus, the sector of the 2D image is



US005797845A

United States Patent [19]

Barabash et al.

[11] Patent Number: **5,797,845**[45] Date of Patent: **Aug. 25, 1998****[54] ULTRASOUND APPARATUS FOR THREE DIMENSIONAL IMAGE RECONSTRUCTION**

[76] Inventors: **Leonid S. Barabash**, 13021 S. 48th St., Apt. 2097; **Aaron E. LaBarge**, 3914 E. Nambe St., both of Phoenix, Ariz. 85044; **Angel T. M. Wang**, 4700 Sandyland Rd. Apt. 37, Carpinteria, Calif. 93013

[21] Appl. No.: **742,403**[22] Filed: **Nov. 4, 1996**[51] Int. Cl.⁶ **A61B 8/00**[52] U.S. Cl. **600/443; 600/459; 128/916**[58] Field of Search **128/916, 660.07, 128/660.01, 661.01; 600/443, 447, 459****[56] References Cited****U.S. PATENT DOCUMENTS**

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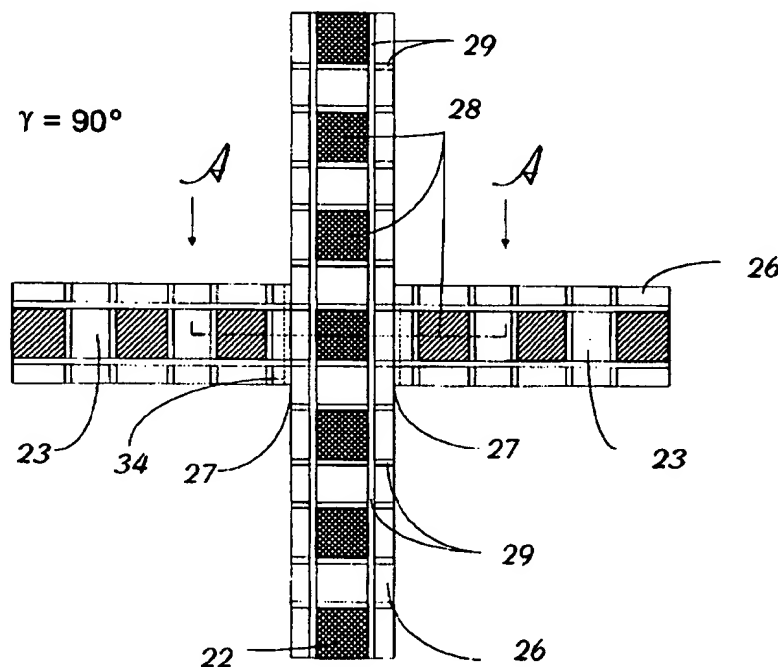
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Primary Examiner—Francis Jaworski**[57] ABSTRACT**

This invention employs an ultrasound apparatus with a phased transducer having transmit and receive array systems to form an electronically scanned ultrasonic "pencil" beam (25) from crossed flat acoustic beams. The flat transmit beams and flat receive apertures are shaped by the arrays with size of individual elements on the order of the wavelength of a generated carrier frequency in a human body. The separation of array functions in the transmission and reception modes reduces the side lobe level and improves the noise performance. A fast method of acquisition of two dimensional images is described. This method uses a property of a dynamic focused and scanned flat acoustic beam together with the ability to shape flat synthetic receive apertures from digitized and memorized amplitude information. The same fast method of three dimensional image reconstruction is suggested, which uses an unfocused acoustic beam generated by a single transducer element together with the ability to form flat synthetic receive apertures in memory.

24 Claims, 15 Drawing Sheets

DOCUMENT-IDENTIFIER: US 5782762 A
TITLE: Method and system for producing interactive,
three-dimensional
renderings of selected body organs having hollow
lumens to enable simulated
movement through the lumen

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BSPR:

In a specific application for generating a
three-dimensional rendering of a
patient's colon, the patient initially undergoes a
selected preparation
procedure. For example, the patient's colon is
initially cleansed and then
inflated with air to permit the acquisition of
unobstructed two-dimensional
images of the colon. Next, the patient undergoes a
CT scan to produce a series
of two-dimensional images of the patient's internal
organs. Preferably, a
spiral or helical CT scanner is employed to provide
a series of uninterrupted
two-dimensional images through the body. The
series of two-dimensional images
are transferred from the scanner to a graphics
computer to effect various image
processing procedures. The dataset corresponding
to the series of
two-dimensional images may be transferred to the
graphics computer in a
compressed format for decompression on the graphics
computer. Alternatively,
the dataset representing the series of
two-dimensional images may be
decompressed on the computer console of the scanner
prior to transfer to the



US005782762A

United States Patent [19][11] **Patent Number:** **5,782,762****Vining**[45] **Date of Patent:** **Jul. 21, 1998**

[54] **METHOD AND SYSTEM FOR PRODUCING INTERACTIVE, THREE-DIMENSIONAL RENDERINGS OF SELECTED BODY ORGANS HAVING HOLLOW LUMENS TO ENABLE SIMULATED MOVEMENT THROUGH THE LUMEN**

[75] **Inventor:** David J. Vining, Winston-Salem, N.C.

[73] **Assignee:** Wake Forest University, Winston-Salem, N.C.

[21] **Appl. No.:** 331,352

[22] **Filed:** Oct. 27, 1994

[51] **Int. Cl.⁶** A61B 5/05

[52] **U.S. Cl.** 600/407; 395/119; 395/924; 128/920

[58] **Field of Search** 128/653.1, 653.2, 128/653.4, 654, 920; 364/413.14, 413.19, 413.22; 378/4, 901; 395/119, 120, 924; 600/407, 410, 420, 431

[56] **References Cited**

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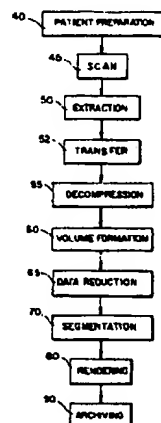
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Primary Examiner—Brian L. Casler

Attorney, Agent, or Firm—Dann, Dorfman, Herrell and Skillman, P.C.

[57] **ABSTRACT**

A method and system are provided for effecting interactive, three-dimensional renderings of selected body organs for purposes of medical observation and diagnosis. A series of CT images of the selected body organs are acquired. The series of CT images is stacked to form a three-dimensional volume file. To facilitate interactive three-dimensional rendering, the three-dimensional volume file may be subjected to an optional dataset reduction procedure to reduce pixel resolution and/or to divide the three-dimensional volume file into selected subvolumes. From a selected volume or subvolume, the image of a selected body organ is segmented or isolated. A wireframe model of the segmented organ image is then generated to enable interactive, three-dimensional rendering of the selected organ.

156 Claims, 25 Drawing Sheets

DOCUMENT-IDENTIFIER: US 6083162 A
TITLE: Method and system for producing interactive,
three-dimensional
renderings of selected body organs having hollow
lumens to enable simulated
movement through the lumen

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BSPR:

In a specific application for generating a three-dimensional rendering of a patient's colon, the patient initially undergoes a selected preparation procedure. For example, the patient's colon is initially cleansed and then inflated with air to permit the acquisition of unobstructed two-dimensional images of the colon. Next, the patient undergoes a CT scan to produce a series of two-dimensional images of the patient's internal organs. Preferably, a spiral or helical CT scanner is employed to provide a series of uninterrupted two-dimensional images through the body. The series of two-dimensional images are transferred from the scanner to a graphics computer to effect various image processing procedures. The dataset corresponding to the series of two-dimensional images may be transferred to the graphics computer in a compressed format for decompression on the graphics computer. Alternatively, the dataset representing the series of two-dimensional images may be decompressed on the computer console of the scanner prior to transfer to the



US006083162A

United States Patent [19][11] **Patent Number:** **6,083,162****Vining**[45] **Date of Patent:** ***Jul. 4, 2000**

[54] **METHOD AND SYSTEM FOR PRODUCING INTERACTIVE, THREE-DIMENSIONAL RENDERINGS OF SELECTED BODY ORGANS HAVING HOLLOW LUMENS TO ENABLE SIMULATED MOVEMENT THROUGH THE LUMEN**

[75] **Inventor:** **David J. Vining**, Winston-Salem, N.C.

[73] **Assignee:** **Wake Forest University**,
Winston-Salem, N.C.

[*] **Notice:** This patent is subject to a terminal disclaimer.

[21] **Appl. No.:** **08/817,901**

[22] **PCT Filed:** **Oct. 27, 1995**

[86] **PCT No.:** **PCT/US95/14022**

§ 371 Date: **Apr. 28, 1997**

§ 102(e) Date: **Apr. 28, 1997**

[87] **PCT Pub. No.:** **WO96/13207**

PCT Pub. Date: **May 9, 1996**

Related U.S. Application Data

[63] Continuation-in-part of application No. 08/331,352, Oct. 27, 1994.

[51] **Int. Cl.⁷** **A61B 5/05**

[52] **U.S. Cl.** **600/407; 345/420; 345/424;**
345/429; 345/433; 128/920

[58] **Field of Search** **600/407, 410,**
600/420, 431; 378/4.901; 345/419-443,
952; 395/924; 128/920

[56] **References Cited**

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Primary Examiner—Brian L. Casler

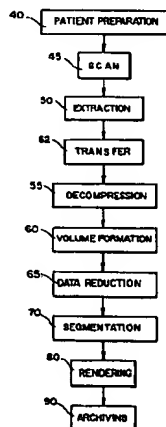
Attorney, Agent, or Firm—Dann, Dorfman, Herrell & Skillman, P.C.

[57]

ABSTRACT

A method and system are provided for effecting interactive, three-dimensional renderings of selected body organs for purposes of medical observation and diagnosis. A series of CT images of the selected body organs are acquired. The series of CT images is stacked to form a three-dimensional volume file. To facilitate interactive three-dimensional rendering, the three-dimensional volume file may be subjected to an optional dataset reduction procedure to reduce pixel resolution and/or to divide the three-dimensional volume file into selected subvolumes. From a selected volume or subvolume, the image of a selected body organ is segmented of isolated. A wireframe model of the segmented organ image is then generated to enable interactive, three-dimensional rendering of the selected organ.

129 Claims, 25 Drawing Sheets



DOCUMENT-IDENTIFIER: US 6236875 B1
TITLE: Surgical navigation systems including
reference and localization frames

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DEPR:

Pre-operative imaging occurs as usual and the skeletal elements may be discriminated from the soft tissue in the image data set as above. In particular, a CT scan of the skeletal elements 10, 20, 30 could be taken prior to the procedure. Processor 104 may then discriminate the skeletal elements and store the pre-procedural image data set in memory 106. Next, the patient is immobilized for the procedure. A radiograph of the skeletal anatomy of interest is taken by a radiographic device equipped with emitters detectible by the digitizer. For example, a fluoroscopic localizer 136 is illustrated in FIG. 7. Localizer 136 includes a device which emits x-rays such as tube 138 and a screen 140 which is sensitive to x-rays, producing an image when x-rays pass through it. This screen is referred to as a fluoroscopic plate. Emitters 142 may be positioned on the tube 138, or on the fluoroscopic plate 140 or on both. For devices in which the tube 138 is rigidly attached to the plate 140, emitters need only be provided on either the tube or the plate. Alternatively, the reference array 110 may be attached to the tube or the plate, obviating the need for emitters on this element. By passing



US006236875B1

(12) **United States Patent**
Bucholz et al.

(10) **Patent No.:** **US 6,236,875 B1**
(45) Date of Patent: ***May 22, 2001**

(54) **SURGICAL NAVIGATION SYSTEMS
INCLUDING REFERENCE AND
LOCALIZATION FRAMES**

(75) **Inventors:** **Richard D. Bucholz**, St. Louis, MO
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Carlos, CA (US); Todd Pope, San
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(73) **Assignees:** **Surgical Navigation Technologies**,
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(*) **Notice:** This patent issued on a continued pro-
secution application filed under 37 CFR
1.53(d), and is subject to the twenty year
patent term provisions of 35 U.S.C.
154(a)(2).

Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

(21) **Appl. No.:** **08/809,404**

(22) **PCT Filed:** **Oct. 5, 1995**

(86) **PCT No.:** **PCT/US95/12894**

§ 371 Date: **Jul. 23, 1997**

§ 102(e) Date: **Jul. 23, 1997**

(87) **PCT Pub. No.:** **WO96/11624**

PCT Pub. Date: **Apr. 25, 1996**

Related U.S. Application Data

(63) Continuation-in-part of application No. 08/319,615, filed on
Oct. 7, 1994, now abandoned.

(60) Provisional application No. 60/003,415, filed on Sep. 8,
1995.

(51) **Int. Cl.⁷** **A61B 5/05**

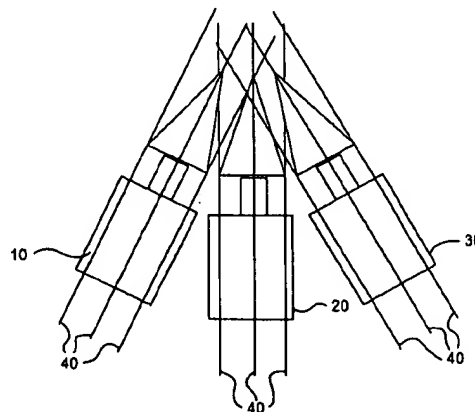
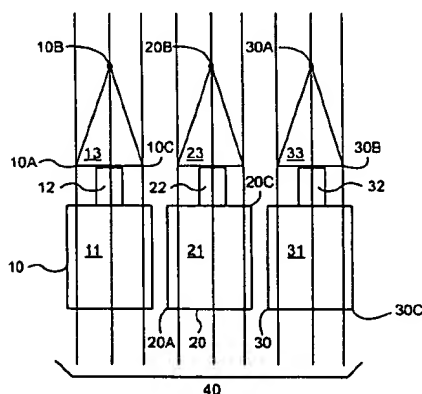
(52) **U.S. Cl.** **600/407; 606/130**

(58) **Field of Search** **600/407, 410,**
600/414, 415, 417, 425, 426, 429, 437;
606/130

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x-rays through the skeletal element 141 of interest, a two-dimensional image based on bone density is produced and recorded by the plate. The image produced by the fluoroscopic localizer 136 is determined by the angle of the tube 138 with respect to the plate 140 and the position of the skeletal elements therebetween and can be defined with respect to procedure coordinates (surgical space). Fluoroscopic localizer 136 includes a processor which digitizes the image on the plate 140 and provides the digitized image to processor 104 for possible processing and subsequent storage in intra-procedural geometry data memory 121. Processor 104 may simulate the generation of this two-dimensional x-ray image by creating a series of two-dimensional projection of the three-dimensional skeletal elements that have been discriminated in the image data set stored in memory 106. Each two dimensional projection would represent the passage of an X-ray beam through the body at a specific angle and distance. In order to form the displaced data set and thus achieve registration, an iterative process is used which selects that a two-dimensional projection through the displaced data-set that most closely matches the actual radiographic image(s) stored in memory 121. The described process can utilize more than one radiographic image. Since the processor 104 is also aware of the position of the fluoroscopic localizers because of the emitters 142 thereon, which are in communication with localizer 108, the exact position of the skeletal elements during the procedure is